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CHAPTER 9

Encoding

Separating Encoding from Retrieval

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Summary

Encoding refers to the acquisition of information: the initial formation of a memory trace. A textbook such as the one that you are now reading can cite references to learning under idealized conditions: simple materials, minimal distractions, and students physically and mentally prepared to learn. Yet how often will such controlled learning conditions occur in the real world? Recall your first year of college, taking what seemed like too many courses, each requiring a different form of studying. Long hours and lots of stress. Or consider having to learn under particularly trying conditions: the U.S. Marine Corps boot camp at Parris Island, South Carolina. The physical training and emotional pressure the recruits experience are well known from film and television. What many of us are not aware of is the academic learning that occurs over 11 weeks of training. Each recruit attends classes and is issued a set of textbooks totaling over a thousand pages. Studying occurs at odd times of the day (or night)—whenever opportunity allows. The recruits are physically fatigued when they need to study. They are under intense emotional pressure and stress (read: FEAR). The recruits are certainly motivated to learn, but the material is so foreign as to appear more like Ebbinghaus's nonsense syllables than meaningful prose. How do variables such as time of day, emotional arousal, incentive, and meaningfulness affect learning? This chapter will consider these and other more usual laboratory variables that affect encoding.

Separating Encoding from Retrieval

This chapter focuses on variables that are thought to influence encoding into memory. The division of information processing into stages of encoding, storage, and retrieval is in some ways arbitrary. After all, better encoding implies that both storage and retrieval will improve also. One means of separating the contributions of each stage is to vary the conditions of learning, or encoding, while holding constant the conditions of storage and retrieval.

The methods of neuroscience offer another means of separating encoding of ongoing experiences into memories, from the storage of memories over time or the later retrieval of memories. Functional neuroimaging studies, the various brain scans, can be used to assess brain activation at each stage of memory. For instance, a tracer element is injected into the blood and a positron emission tomography (PET) scan maps where this element travels to in the brain during the performance of a cognitive task. The difference in activity levels in areas of the brain during performance of different tasks, such as studying a list of words versus recognizing previously studied words, may indicate which brain regions are implicated in each stage. In one type of imaging study, the brain activity during study of each individual item was measured. This activity was then correlated with whether those items were recalled or forgotten. Certain areas in the left hemisphere were found to be more active during the study of verbal items that were recalled and were less active during study of items that were later unrecognized (Wagner et al., 1998). Similarly, certain areas of the right hemisphere were more active during encoding of photographs of scenes that were subsequently recognized than during the study of photographs that were not recognized (Brewer et al., 1998). So far, the technology does not exist to routinely scan the brains of learning and remembering subjects, so we will continue to differentiate storage and retrieval based on more traditional methods of dissociation.

Some Basic Variables in Encoding

In the laboratory, encoding into episodic memory is often studied. Episodic memory is remembering information based on its occurrence at a particular time and place. Free recall of lists of words, sentences, or pictures are tests of episodic memory: recalling the items you just saw, here in the laboratory. As students and learners, we may have a more practical interest in learning that occurs outside of the lab. Yet in order to better study the effects of encoding, the researcher needs to have control over the task from presentation until testing.

A number of factors are reviewed in the several following sections: rehearsal, imagery, and arousal, just to name a few. Several of these factors are summarized for quick reference in Box 9.1.

Elaborative Rehearsal

The role that rehearsal plays in remembering has been considered in several previous chapters. The number of words that are recalled from a list typically correlates with the number of rehearsals the words receive (Chapter 6). This is consistent with the dual-memory

BOX 9.1

Summary of Some Factors Related to Encoding and Their Definitions

Characteristics of the To-Be-Learned Material

Word Meaningfulness. Meaningful words are ones having some combination of the following: a high frequency of occurrence in language and print, are easily pronounced, have many associations to other items, and are more imagable.

Concrete/Abstract Words. Words that refer to actual, physical things, and that tend to be imagable and have a number of associations versus words that refer to nonphysical abstract ideas.

Imagery. The degree to which items can be mentally imaged. Pictures or objects actually seen are better remembered than if their names are simply read.

Factors in the Presentation of To-Be-Remembered Materials

Testing Effect. Taking a practice test on recently studied material instead of additional study of the material. A criterion test given later assesses the effects of the additional study versus practice testing.

Spacing of Repetitions. Two presentations of an item can be massed, one immediately after another, or spaced, with some interval of time or some other items occurring between repetitions.

Isolation Effect. An unusual or distinctive item that stands apart from the other items in a series.

Cognitive Strategies

Maintenance Rehearsal. Somewhat passive, repetitive thinking about to-be-remembered material.

Elaborative Rehearsal. Thinking about the material in such a way as to require more cognitive effort, to activate more associations, or to produce a more distinctive memory representation.

Subject Factors

Arousal. Mental or physiological arousal, associated with circadian rhythms, stimulant and depressant drugs, or emotional arousal.

Incentives. The provision of explicit rewards for learning or remembering.

Incidental versus Intentional Learning. The participants are instructed to remember the material ("Please try to remember this") or the participants are simply asked to process the material in some other way ("Is the word a food or an animal?") without mention of a later test of retention.

distinction, which asserts that rehearsal in short-term memory promotes better long-term representation of the rehearsed information (Chapters 7 and 8). However, all rehearsal is not the same; there seems to be some qualitative differences in rehearsal.

One important distinction that we can make is between elaborative rehearsal and maintenance rehearsal. The two terms derive from the levels-of-processing approach of Craik and Lockhart (1972), which posits that information can be processed to a greater or lesser extent, and thus by analogy to different "depths" along a continuum from shallow to deep processing. *Maintenance rehearsal* is a form of shallow processing, a recycling of information in order to keep it available in short-term memory or the phonological store. We use maintenance rehearsal to remember a phone number long enough to dial it, simply repeating the number over and over until it is no longer needed. Maintenance rehearsal can be effective for short-term retention, and our research participants will choose to use maintenance rehearsal if they know they will be allowed uninterrupted rehearsal until the time of recall (Wixted, 1991).

Elaborative rehearsal is processing in which to-be-remembered material is related to other information. There is an active or deliberate attempt to cognitively interact with, reflect on, or use the to-be-remembered information, which is why elaborative rehearsal represents deep processing. We use elaborative rehearsal to memorize a phone number by, for example, looking for meaningful patterns in the numbers. The two forms of rehearsal also produce qualitative differences in memory: Elaborative rehearsal produces more of an episodic memory, a recollection of having studied the material at a particular time and place. Maintenance rehearsal does not: The facts seem familiar, but you cannot remember how or where you learned them (Gardiner et al., 1994).

The idea of elaborative rehearsal is a central theme in this chapter: Many of the variables that affect encoding in one way or another can be interpreted as instances of elaborative processing.

What Exactly Is Elaborative Processing?

A typical procedure for manipulating processing depth is to present a list of items and have the students answer a question about each item as they occur. Different types of questions require different levels of processing of the target items. For instance, given the target word BONE, the various questions asked might be, "Does the presented word contain the letter *e*, does it rhyme with *train*, is it an *animal*?" These questions require different kinds of processing: the surface form or appearance of the word; the sound of the word; or the meaning of the word. Later, the subjects are tested for memory of the list. Items that received deeper processing during presentation are more likely to be recalled (Craik & Tulving, 1975).

The analogy of elaborative processing to deep processing may be a useful description, but this does not specifically define what elaboration is. At least three hypotheses have been offered: elaboration, distinctiveness, and effort (Horton & Mills, 1984). *Elaboration* refers to expanding a newly formed memory trace. Something is remembered better if it can be related to other known facts. If you have to remember the word AARDVARK, you might try to think of any associations to the word or any facts you know about aardvarks. Figure 9.1 illustrates the sets of possible associates that could be activated by the target words CRAB, FACT, and LAMP (Nelson & Schreiber, 1992). The words CRAB and FACT have larger sets of associations that could be activated than does the word LAMP. (CRAB and LAMP, however, could evoke specific mental pictures or images, whereas FACT does not. Imagery in encoding is discussed in a subsequent section.) Elaborated traces have more connections or associations to other memories. This increases the number of possible retrieval cues, and so elaboration affects both encoding and retrieval.

Alternatively, elaborative rehearsal may increase the *distinctiveness* of the memory. A distinctive memory is one that stands out, is more easily discriminated from other memories, and will suffer less interference from other memories during retrieval. Unlike elaboration, the distinctiveness hypothesis allows that shallow processing may sometimes lead to good retention, as long as the memory representation is distinctive. For instance, orthographically distinct words, that is, words that are unusual looking (such as LYMPH or AFGHAN)

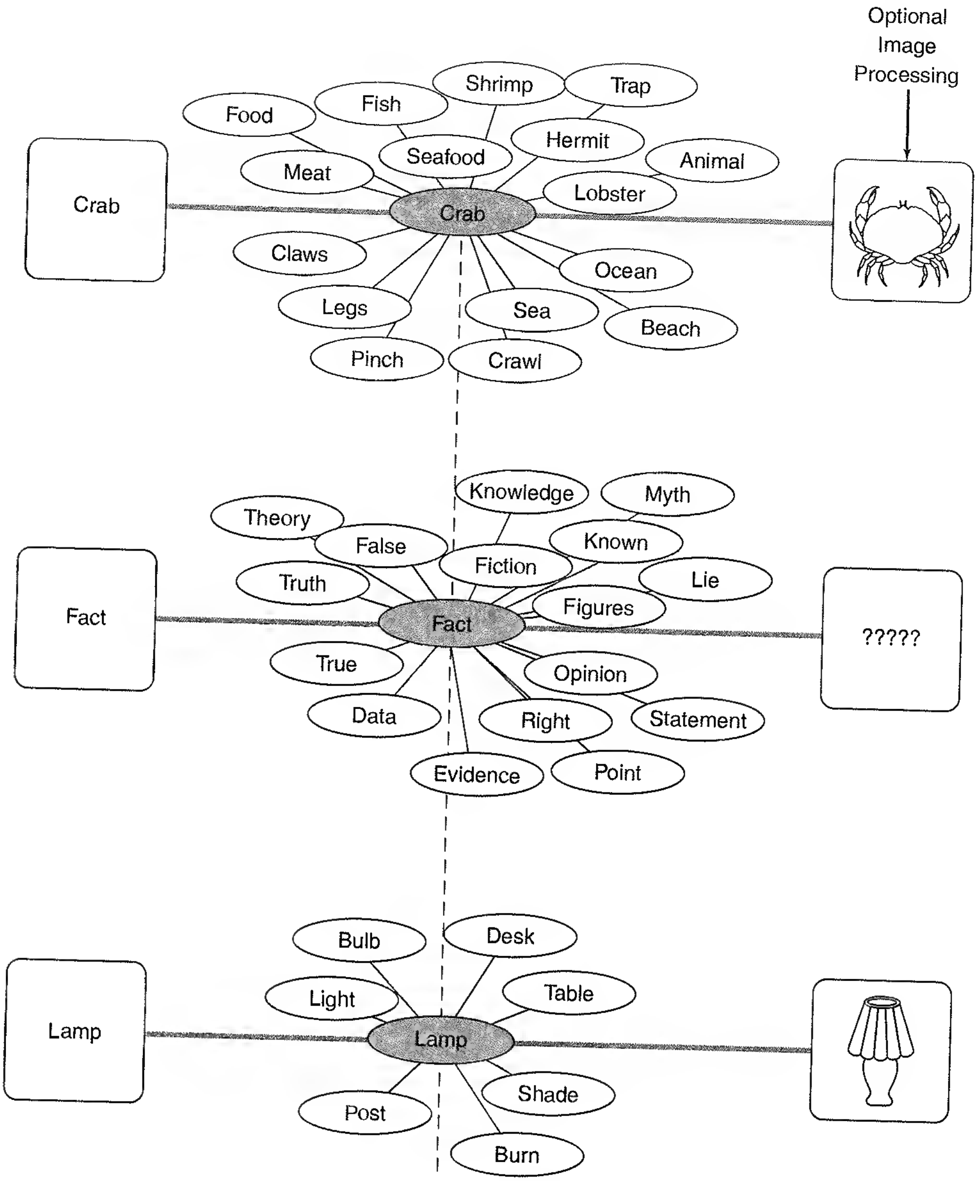

FIGURE 9.1 Hypothetical Elaborative Encoding of Three To-Be-Remembered Words: CRAB, FACT, and LAMP. Each word activates associated words and ideas, although the size of the associated sets vary. In addition, some words may evoke a mental image of the word's referent.

Source: From "Word Concreteness and Word Structure as Independent Determinants of Recall," by D. L. Nelson and T. A. Schreiber, 1992, *Journal of Memory and Language, 31*, p. 240. Copyright © 1992 by Academic Press. Reprinted with permission.

are recalled better than are orthographically common words (such as LEAKY or AIRWAY), even when the words are matched for meaningfulness and frequency of occurrence in language (Hunt & Elliot, 1980).

The third possibility is that elaborative processing requires more effort, and it is actually the amount of effort expended that determines retention. *Cognitive effort* can be measured by the impairment in performance on a second task done simultaneously with the memory task. For example, as a to-be-remembered list of words is presented, the subject must also push a button every time a tone stimulus sounds. Increasing the cognitive effort required in the memory task will lead to a corresponding slowing of reaction time to the tone (Eysenck & Eysenck, 1979). Elaborative rehearsal in the memory task leaves less capacity available for the stimulus-detection task. The results of such a dual-task procedure are shown in Figure 9.2. More words were recalled when the participants had to make a deep judgment ("Does the word name something that is edible?") rather than a shallow judgment ("Does the word contain a letter *e*?") about the word, but it took them longer to react to a tone or light stimulus that occurred during or near to the deep judgments. The slowed reaction times are an indicator of the cognitive effort being expended on the judgment task.

The various definitions of elaborative rehearsal can be illustrated by applying the notion of processing depth in several studies of memory for faces. Subjects in Bower and Karlin's (1974) study were shown high school yearbook photos. In one condition, the subjects made simple judgments about the faces (e.g., identify gender). In the other condition, they were asked to make character judgments for each face (e.g., "Does this person look

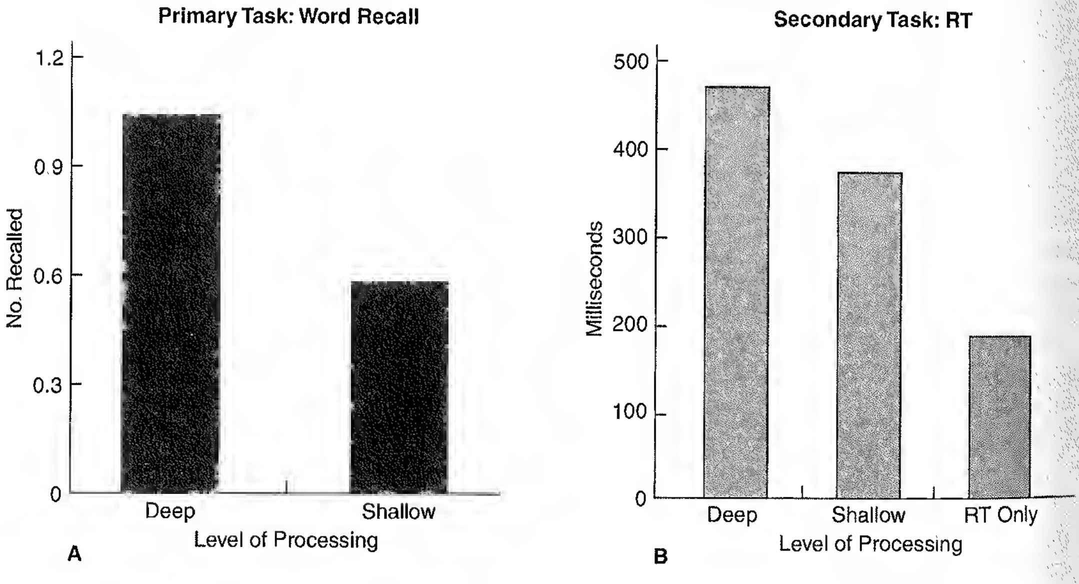

FIGURE 9.2 Dual-Task Performance Illustrating Trade-Off between Cognitive Effort and Reaction Time.

Source: Eysenck & Eysenck, 1979, p. 479 and p. 481.

honest?"). The first condition presumably requires shallow processing and the second condition deeper processing. When tested afterwards, the character judgment participants correctly recognized more faces than did the group that made shallow judgments. If you want to remember a face, ask yourself, "Would I buy a used car from this person?" Following on Bower and Karlin's study, Winograd (1981) had participants study faces for distinctive features. For instance, "Does this person have a large nose? Is he wearing glasses?" This turned out to be an effective means of increasing retention, and the more features searched, the better memory for the studied faces was. Looking for distinctive facial features could be considered shallow processing because it focuses on surface features, but it does increase distinctiveness. What about the role of cognitive effort? Given deep-processing instructions, participants make more eye movements when inspecting the pictures, implying more processing effort (Bloom & Mudd, 1991). Deep-processing subjects also report more interest and involvement in the task, whereas the shallow-processing groups find their task boring and undemanding (Sporer, 1991). So, why does elaborative processing enhance face memory? There is experimental support for all three hypotheses of elaboration, distinctiveness, and cognitive effort.

How Can Elaborative Processing Be Enhanced? The techniques used in the various mnemonic devices discussed in Chapter 6 exemplify elaborative processing. In the keyword mnemonic, a mediating word is selected to connect two target items. How can you remember that Pittsburgh is a steel-producing town? Link Pittsburgh to the Steelers, and then to steel. In the narrative method, a story is fabricated to link together a series of target words. In the pegword and location mnemonics, images are formed of the target and the mnemonic cue. These methods require meaningful analysis of the targets, the creation of distinctive representations in memory, and cognitive effort. Not surprisingly, the mnemonics work.

Organizing the to-be-remembered material is another means of elaborative processing. For example, in remembering a list of words from identifiable categories (animals, tools, foods, etc.), the words can be more readily interrelated in memory, which is what elaboration is.

Conclusions about Elaboration. "People will probably learn more if we can find ways of making them work harder at encoding and if they are encouraged to deal with new information in terms of its meaning and semantic content. Getting students to simply repeat material or spend more time looking at it is not the most efficient way to ensure they will learn and remember the content" (Kulhavy, Schwartz, & Peterson, 1986, p. 122). This summary reminds us of several aspects of elaboration: effort, meaningfulness, and active rehearsal.

Imagery and Memory for Pictures

Verbal encoding is not the only way of learning material, and it may not be the best. Visual coding can be extremely effective. We see this both through the use of imagery and in the recall of pictures versus words.

If words are presented for study, *concrete* words are typically recalled better than *abstract* words. Concrete words refer to things that can be readily imagined or pictured (such as the word CRAB), whereas abstract words refer more to ideas (such as the word FACT). Concrete words show a memory advantage over abstract words, as shown in a variety of learning situations (reviewed by Nelson & Schreiber, 1992).

Memory for pictures is often remarkably good. In one study, subjects were shown over 2,200 photographs presented in 2-hour sessions on 4 days. During testing, 280 pairs of slides were presented and the participants had to decide which picture in each pair had been seen before and which one was new. Correct choices were made over 90 percent of the time (Standing, Conezio, & Haber, 1970). Granted, this procedure is not comparable to that typically used to test word memory. Photographs have much more detail than a printed word, allowing many cues to discriminate old from new photos. Still, the number remembered is impressive.

Objects are recalled even better than pictures. Given stimuli displayed in one of three ways, actual objects were better recalled than were photographs of the objects, which were in turn better remembered than the printed name of the objects. This is also one case in which younger students did as well as older ones: fourth graders were as good as college students in recalling objects (Bevan & Steger, 1971).

Instructing participants to visually image to-be-remembered items such as words often increases recall (e.g., Roediger, 1980). We saw further evidence for the beneficial effects of visual imagery with several of the mnemonic techniques described in Chapter 6. The peg-word system and the method of locations both use visual imagery to aid recall.

Why would picture memory be so much better than word memory? One reason is that pictures can be remembered with two encodings, one visual and the other a verbal translation of the picture. This is referred to as *dual coding* (Paivio, 1969). Another advantage for pictures is that the memory is more specific and distinctive than is the memory for an unelaborated word. As shown in Figure 9.1, the words CRAB and LAMP can take on specific images. For example, imagine remembering the word DOG versus a simple line drawing of a dog. The drawing cannot be too generic; it must show some kind of dog. (A large dog or small? Pointy or floppy ears?) This image may activate other knowledge of dogs, possibly unique facts that the word DOG does not retrieve, or it may remind us of a particular dog.

Picture memory benefits from elaborative processing, just as does word memory. Bransford, Nitsch, and Franks (1977) showed students a photograph of a living room, and gave orienting instructions to induce different forms of processing. Some were told to try and find small hidden *x*'s within the picture. Another group was told to think about the kinds of actions they could perform with the objects. The students were then unexpectedly asked to recall as many objects from the picture as possible. The *x* group remembered only about 8 objects, but the action group remembered over 20. What is nice about this manipulation is that the *x*-searching subjects did closely attend to and scan the picture. Even so, their recall was poor.

Meaningfulness

Ebbinghaus compared his retention of poetry versus nonsense syllables. He found that the meaningful material was remembered better than the nonmeaningful, a conclusion that has been repeated for 100 years now. But what exactly is meaningfulness? And how can we increase it?

The starting point for analyzing meaningfulness was to discover those variables that correlated with ease of learning. If we think of meaning as something we already know something about, then meaningful words should be familiar words. Words rated as being meaningful do have a high *frequency* of occurrence in the language: we hear them, read them, and use them often.

Meaningful words are high in ease of *pronounceability*. This may be related to familiarity and frequency. This may also involve the phonological store of working memory: New words are rehearsed there during acquisition.

Meaningful words are often more *imagable*. A mental image or a remembered picture can often be generated for meaningful words (DOG versus LIBERTY). (In attempting to remember an abstract idea such as LIBERTY, you might try to make it concrete, possibly by remembering it as the Statue of Liberty.) The meaningfulness of a word can overlap with its concreteness and imagability.

Finally, meaningful words have more *associations* to other ideas and knowledge. In comparison to the features mentioned previously, the strongest predictor of memorability was the frequency with which a word is given as an association to other words (Rubin & Friendley, 1986). We can use these associative links to activate related knowledge. This gets at one definition of elaboration: A meaningful item can be elaborated better in memory by drawing on an extensive network of interassociations. This network can involve semantic memory (general knowledge) and episodic memory (personal recollections).

The preceding listing of characteristics suggests that meaningfulness has to do with prior knowledge: Meaningful material is stuff you already know about. Generally, learners use knowledge they already possess to relate new items to this existing knowledge. The implication is that the more you know, the more you can learn. This truism has been substantiated in comparing people who are experts in certain domains and novices. For example, if shown various arrangements of chess pieces on a board, chess masters will remember them more accurately than less experienced players. This is particularly true if the pieces are in a meaningful arrangement (Gobet & Simon, 1996). When given 31 lines of a computer program to memorize, advanced student programmers learned them more readily than did students of intermediate ability. Again, the advantage for the experts was dependent on the program lines being in a logical sequence, and the advantage virtually disappeared when the program lines were scrambled (McKeithan et al., 1981).

This expertise in remembering does not indicate exceptional memory ability per se, but rather *domain-specific knowledge*. There are certain subject areas (domains) in which we each possess detailed and specific knowledge. You can recall information well from areas with which you are familiar. College students who were knowledgeable about baseball could remember fabricated baseball facts better than less knowledgeable students. Students knowledgeable about music remembered more fabricated facts about music than about baseball. A general memory ability does contribute. In this same study, the ability to memorize meaningless associations was related to learning about either topic. But apart from this, there was a significant contribution of domain-specific knowledge (Kuhara-Kojima & Hatano, 1991).

How Can Meaningfulness Be Used to Increase Learning? One suggestion is to use existing knowledge to make new information more meaningful. Learners themselves may attempt to create meaningfulness in otherwise unfamiliar material. Given a lengthy, random series of items, one strategy is to chunk them into more meaningful units. For example, one 38-year-old savant (otherwise described as having a mental age of 11) had exceptional numerical memory ability. He would memorize things like city populations, distances between cities, or the number of rooms in various hotels. He could readily remember strings of numbers, such as 4836179621. How? "When I saw this number, I read it as 4, 836, 179, 621. I remembered 4 because of the fourth of July, . . . 836 was the Chinese population of the State of Texas in 1910, . . . 179 is the number of miles from New York to Harrisburg, and 621 is the number of a house I know in Denver" (Treffert, 1989, p. 74). Another mnemonist, Hans Eberstark, has exceptional language-learning abilities and, in fact, spent his working life as a translator. He readily picks up words in new languages, mainly by looking for similar-looking or -sounding words in other languages with which he is familiar (Bernstein, 1993).

Meaningfulness can also be provided to the learner. Bransford and Johnson (1973) found that a list of vaguely worded instructions could be more readily recalled when a label was given (Flying a Kite or Washing Clothes). Without the label, the list of instructions seems fairly random. Similarly, we saw earlier that classical music pieces were remembered better when they had been given concrete labels (Delis et al., 1978).

Presentation Variables

Testing Effects

Say you have a big test tomorrow and you are planning your study strategy. Given that you have studied the material once, should you study it a second time, or should you now take a practice test on the material? Students would probably think that more studying is better than testing. After all, it is called "studying" for a test. However, a significant finding from current research is that taking a test on the material is often more beneficial to remembering (on tomorrow's exam) than is additional study of the material. This finding is referred to as the *testing effect*: the greater benefit of taking a test over additional study, as assessed on later retention of the studied material.

In the prototypical design for a study of testing effects the research participant is exposed to the material two (or more) times, and then takes a final test on the material. In the standard condition, students might study the material, and then study it again. We can label this condition S-S. In the tested condition, the students would study the material, and then they would take a test on the information. Therefore, this is condition S-T. Some time later, a final test is given to both conditions to see which group remembers more: the one that studied twice, or the group that studied once and was tested once. We are interested in performance on the final test. Thus the design of such studies is as follows:

Standard condition, S-S: study once.... study again......Final test
Tested Condition, S-T: study once.... practice test....... Final test

Roediger and Karpicke (2006) used this design to assess learning and retention of new information in the form of textbook-like paragraphs. Some college students studied the material twice; other students studied once and then wrote as much as they could remember. On the final (the real) test given a few minutes later, the S-S group remembered slightly more. If the final test was not given until two days or one week later, the S-T condition remembered more than did the study-twice condition.

Roediger and Karpicke (2006) extended the above design to compare a condition in which students studied four times (S-S-S-S) and a condition in which the students studied once and then made three practice attempts at recalling the information (S-T-T-T). The final test was given one week later to measure long-term learning of the material. Recall on this final test showed that more testing led to more remembering; and more studying led to less remembering. Testing your memory on what you have just studied may help you remember better in the long run than simply studying more. This may sound counterintuitive, and indeed the students in this experiment thought so also. Some students had studied the material four times, and they thought for sure they would remember more on the test than did those who had studied only once. However, a week later the S-T-T-T group recalled more.

Why is testing retention better than additional studying? Several explanations have been considered. (You should know by now that there is never just one explanation, the correct one.) One explanation is that taking a practice test is just another version of studying. After all, the material is presented a second time, although now in the form of questions and the students' answers. This re-exposure during testing may be a contributing factor to the testing effect, but it is not the whole explanation. Memory in the S-T condition is not simply as good as the S-S condition. The tested students perform on delayed tests better than the students who explicitly studied more. The testing manipulation is doing more than simply providing a second study exposure.

A more likely explanation is that the test provides a more challenging re-studying of the material than passively reading it over a second time. Answering test questions requires more cognitive effort than re-reading.

A third possibility is that the practice test mimics what the students are required to do on the final test, that is, retrieve the information from memory. According to the transfer-appropriate processing approach to learning (described in Chapter 7), memory retrieval is better when the operations performed at retrieval (here referring to the final test) match the operations performed when the information was being encoded (here, either reading the material or taking a preliminary test on it). The cognitive operations on the practice test are a closer match to those on the final test.

Still, the testing effect raises a number of procedural questions about its generality. When recalling correct information during the practice test, the subject is (obviously) exposed to the material a second time—at least, what can be correctly recalled. But what about the material that was not tested on the practice test? Does testing some of the information aid memory for items that were not tested initially? It seems that even the untested information is helped by preliminary testing (Chan, McDermott, & Roediger, 2006).

Testing usually implies feedback: Which questions did you get right or wrong? Does feedback need to be given on the practice test for any benefit to accrue? The best final recall occurred when the participants took a short answer type of practice test *and* received feedback. This was better than studying a second time. The practice test alone, even without feedback, was still sometimes better than re-studying a second time (Kang, McDermott, & Roediger, 2007). Another way to look at feedback is to consider that, on the practice test, some questions are answered correctly and some are not. Maybe all the subject needs is a refresher on the unremembered items. Karpicke and Roediger (2007) used a procedure in which study trials and tests alternated until the list was learned. Trial by trial, items from the list that were remembered on a test were dropped from the next presentation of the list. Only the forgotten items were re-presented. Re-studying the items you already remember does not help, but re-studying the items you forget does help. However, you still need to practice recalling the previously remembered items on successive tests.

There can be negative effects of testing. On the final test you might remember the wrong answer from the practice test. Or, some answers on the final test look familiar because, well, they are familiar. They were the distractors used on the practice test but are selected on the final test because they look familiar. The negative effects of "misinformation" are discussed more in Chapter 11.

Isolation Effects

One commonly held belief about memory is that unusual or distinctive material is better remembered. Helena von Restorff, a Berlin Ph.D. of the 1930s, studied this phenomenon. In presenting a list of to-be-remembered items, the manner of presentation of one item was made distinctive. For example, if the other words were printed in black, one word would be printed in red. If the list consisted mostly of words, one item would be a number. The distinctive item, distinctive in the context of the list, was usually learned more quickly or remembered better. This effect has been called the *von Restorff effect,* or the *isolation effect,* in reference to isolating one item in the list. A nice example of the isolation effect is a television commercial that contains no sound whatsoever; the message is signed by an actor, and printed at the bottom of the screen. The sudden silence in the midst of the other attention-seeking ads certainly stands out.

The von Restorff effect is typically attributed to enhanced encoding of the distinctive item. Perceptually, an isolated item stands out from the others. It should garner more attention, be rehearsed more, and possibly be more elaborated in memory. Such explanations define a "differential processing" view (Waddill & McDaniel, 1998). Brain-wave measures of orienting indicate subjects notice and attend to the isolated item (Fabiani & Donchin, 1995). However, enhanced recall of the isolated item might be because it is more distinctive during retrieval. Against a blur of memories of many similar items, the isolated item may be distinguished and thus recalled (Hunt, 1995).

Something of an isolation effect can occur in remembering characteristics of people. Atypical behavior from someone we know well would stand out and might then be well remembered. In a study by Hastie and Kumar (1979), hypothetical individuals were described by trait labels to induce a personality impression in the participants. For instance, someone would be described as intelligent, clever, quick, and smart. After this, a list of 20 to-be-remembered behaviors of this hypothetical person was presented. Most were congruent with the initial personality labels, for example, the person was said to have won a chess tournament, attended a symphony concert, or liked reading history. In addition, one or a few incongruent behaviors were presented: He failed math twice, or he was always getting lost. When the participants tried to recall the list of behaviors, the incongruent ones were usually recalled better than the congruent behaviors, especially when the incongruent behaviors were few in number. For example, whereas about 50 percent of the congruent behaviors were recalled, a single incongruent behavior in the list was recalled 77 percent of the time.

Isolation effects occur in animal memory also. Rats were trained to make the correct sequence of turns in a maze with seven choice points. One choice point was made distinctive by painting stripes on the wall and putting sandpaper on the floor. Separate groups of rats had the second, fifth, or seventh choice made distinctive in this manner. Fewer errors were made in learning the correct turn at the distinctive choice point than in the others (McLaughlin et al., 1968).

Other research has shown a more complex and interesting pattern of results when memory for the whole list is considered. Whereas the isolated item is well recalled, this may come at the expense of memory for items before and after it in the list. For example, suppose the following partial list of words is presented: table, dog, tree, grass, COLUMBUS, school, coffee, and soup. The enhanced recall of the distinctive item (COLUMBUS) can impair recall of the words just before it (GRASS and TREE). Tulving (1969) called this a *retrograde amnesic effect.* Retrograde amnesia is defined as forgetting for the past, and is usually used in the context of a traumatic cause for the amnesia. In Tulving's experiment, the participants did not actually experience trauma from the word COLUMBUS, but the unusual word was surprising enough to have a retrograde amnesic-like effect.

In addition, the distinctive item may impair memory for the words that follow it. Detterman (1975) found an *anterograde amnesic effect,* in which words after the distinctive one were forgotten. In the preceding example, SCHOOL and COFFEE might not be recalled. The results of one of Detterman's experiments are shown in Figure 9.3. A list of 15 words was presented auditorily, with the distinctive item in the eighth position being

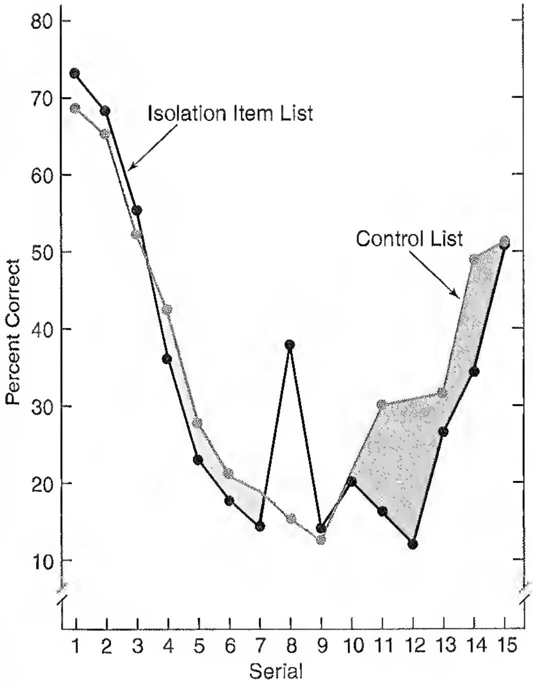

FIGURE 9.3 The Isolation Effect in the Recall of a List of 15 Words. A distinctive item occurs at the eighth position in the experimental list. The distinctive item is well recalled, but there is some forgetting of the items that preceded and followed it in the list.

Source: From "The von Restorff Effect and Induced Amnesia: Production by Manipulation of Sound Intensity," by D. K. Detterman, 1975, *Journal of Experimental Psychology: Human Learning and Memory, 1,* p. 626. Copyright © 1975 by the American Psychological Society. Reprinted by permission.

presented much more loudly than the remainder of the words. The graph nicely illustrates the enhanced retention of the von Restorff item, the corresponding retrograde amnesic effect (the shaded portion before the distinctive item), and the anterograde amnesic effect (the shaded portion after). Note also that the first and last items of the list are recalled better than the middle items, which we earlier labeled primacy and recency effects.

Seductive Details

The trade-off in remembering a distinctive item at the expense of a less distinctive item is shown by the effects of *seductive details* on memory. Often, a lecturer or writer will cite an interesting but tangential fact to help maintain the audience's attention, hoping that the interesting tidbit will increase their memory for the main topics and central facts of the lecture or text. Students might find the topic of classical conditioning less than invigorating, but their interest would likely increase upon learning that John Watson, who conditioned Little Albert to fear a lab rat (Chapter 3), reputedly had some fears of his own. He slept with a night-light and never drove.

Unfortunately, people may remember the tangents but not the main facts. This has been referred to as the *seductive detail effect.* Novel, concrete, or personally involving details grab attention and thus memory, in contrast to the more abstract, general material the details were meant to illustrate. Why do seductive details impair recall? One possibility is that they distract attention away from the main ideas of the text or lecture. Processing tangential facts comes at a cost to processing other information. But there can be a second effect, as well. Interesting tidbits may disrupt the flow of the text or lecture. The coherence of the material may be interrupted, and the student may not be able to organize the ideas. Seductive details are less harmful when presented at the end of the passage, presumably after the readers have already formed an outline for the material (Harp & Mayer, 1998).

Spacing Effects

Hardly any student has not heard the admonition, "Study every night, don't wait and cram at the last minute." Thus, you are already familiar with the *spacing effect*: Spaced practice (or distributed practice, as it is sometimes called) leads to better retention than does massed practice. If something is to be studied two (or more) times, it is better to distribute the repetitions than to mass them close together. Like the serial-position curve, this is an amazingly general observation of learning (Dempster, 1996).

Why does spacing repetitions produce better retention? Several theories have been offered over the years. No single explanation seems to accommodate all of the available data, so contemporary theories often advocate two-process accounts. (According to the principle of parsimony, when the simpler explanation does not suffice, we can adopt a more complex one.) Each explanation has led to novel experimental tests that offer insights into the effects of spacing.

Hypothesis 1. A second massed presentation of an item interferes with ongoing processing of the first presentation. Processing the first presentation (referred to here as P1) is terminated prematurely by a massed repetition (or P2), and so the massed practice decrement is due to poorer retention of P1. We might refer to this as the *retrograde amnesia* hypothesis.

One way to assess whether P1 is less remembered during massed, as opposed to spaced, trials is to tag P1 and P2 differently. That is, present some slightly different information along with the two presentations and see which is remembered better. By presenting the target word in different modalities at P1 and P2 and then asking participants to recall not only the items but also whether they had been auditory or visual, we find that it is the second item and not the first item that suffers interference with massed repetitions (Hintzman, Block, & Summers, 1973).

Hypothesis 2. Participants attend less to a second presentation when it is repeated too soon. The idea here is that participants are attempting to remember a list of items, and so processing must be distributed across the items. A massed P2, seeming so familiar, is skipped through to devote more time to other items. Shaughnessy, Zimmerman, and Underwood (1972) actually let participants pace themselves through the list by giving them the remote control to the slide projector. They skipped through immediate repetitions, but spent more time on repetitions that occurred after longer delays. Thus, this can be labeled an *attention-deficit* hypothesis.

Further support for the attention-deficit explanation of massed repetitions comes from monitoring eye movements across a photograph. The number of fixations decreases to pictures that are presented again in a list, as compared to novel pictures. Eye movements are reinstated by a slight change in the image, such as changing the location of objects in the picture (Ryan, Althoff, Whitlow, & Chen, 2000).

Hypothesis 3. Spacing repetitions of a target item leads to slightly different encodings. Long-term recall is enhanced by having multiple retrieval cues, or routes, to the target. When the two occurrences are more widely spaced, they might be encoded somewhat differently into memory. For example, given the list TABLE, FORK, SCHOOL, BOOK, TABLE, the first TABLE may be encoded as a kitchen item and the second as a classroom item. Recalling either FORK or BOOK might aid retrieval of the target word TABLE. This explanation is known as the *encoding variability hypothesis.* Back-to-back TABLEs are likely to be encoded similarly, both as kitchen items, for example.

Encoding variability suggests that massed repetitions might not be so bad if P1 and P2 are encoded differently, just as they supposedly are when repetitions are spaced. Different encodings can be simulated by using homographs, or words that have two different meanings, as stimuli and biasing their encodings. For example, the homograph FOOT is first presented in the context of "inch," and the second time in the context of "toe." Words presented in this fashion do not show a massed-practice decrement (e.g., Gartman & Johnson, 1972). That is, using our previous example, FOOT is well remembered even though the two presentations were massed. This is a contrived manipulation, and some have argued that the homographs are actually different words (Martin, 1975), but it does illustrate the reasoning behind encoding variability. The general idea is that items may be encoded differently when they are encountered on separate occasions.

One consensus idea that has emerged from all the research on distributed practice is that "a little forgetting may be good for learning" (Cuddy & Jacoby, 1982; Krug, Davis, & Glover, 1990). With a massed second presentation, there is a false feeling of knowing when in fact the material is not known well at all. After a longer spacing between the two presentations, the participant may recognize that the item has been temporarily forgotten, which should heighten processing of the repetition. In addition, longer spacings give an opportunity to practice recalling the target material from long-term memory.

Effect of Retention Interval. As universal as the spacing effect is, there is one deviation to the spaced-is-better rule: If retention is tested after a short delay interval after the second presentation, massing is sometimes better. For example, Balota, Duchek, and Paullin (1989) used a modified paired-associate procedure with college-aged and elderly adult subjects. Spacing varied from having back-to-back presentations to presentations separated by 20 other items. Item pairs were sometimes tested immediately, or after a delay of about 20 items. A portion of their results are shown in Figure 9.4. Both younger and older subjects recalled more massed items on the immediate test and recalled more spaced items on the delayed test.

Other examples can be cited from several diverse procedures, using animals or humans, and involving shorter or longer time spans (Peterson, Hillner, & Saltzman, 1962; Medin, 1974; Singh et al., 1994). Massed presentations produced better recall in testing occurring shortly afterward; spaced presentations were better when testing was delayed.

There is a significant implication from these sorts of results. One can arrange a situation to make learning appear to be easy or one could arrange it to make learning lasting. Imagine having several things to learn (facts, vocabulary words, or skills as examples). Practicing a single fact or skill in a massed fashion should lead to rapid improvement. With massed practice, you may attain a superior level of performance during the study phase. Intermixing the facts or skills in the practice sequence will slow learning, as you apparently forget from one trial to the next. Yet in the long run, learning and transfer will be increased by intermixing rather than massing the study items (Schmidt & Bjork, 1992).

Although we are all familiar with the spacing effect, at least one researcher claims it is not practiced enough in education (Dempster, 1988). For example, textbooks could be

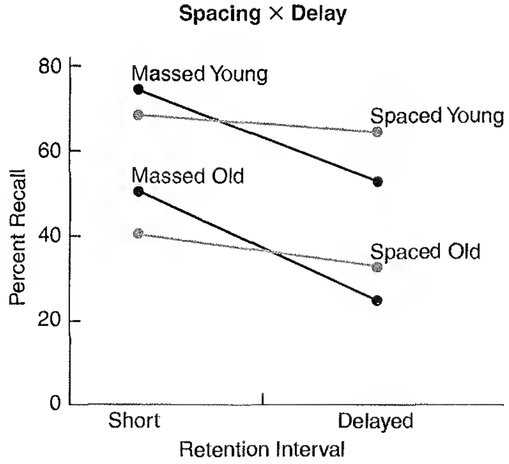

FIGURE 9.4 Mean Percent Correct Recall in a Continuous Paired-Associate Procedure by Younger and Older Subject Groups. Items were presented either massed (presented 1 pair apart) or spaced (presented 20 items apart) and tested shortly after (2 items later in the list) or after a longer delay (20 items later).

Source: From "Age-Related Differences in the Impact of Spacing, Lag, and Retention Interval," by D. A. Balota, J. M. Duchek, and R. Paullin, 1989, *Psychology and Aging, 4,* p. 7. Copyright © 1989 by the American Psychological Association.

written that repeat certain ideas from chapter to chapter, thus ensuring repetition and spacing. Semester and quarter systems do not allow for the widely spaced repetitions (over intervals of months) that Bahrick thinks are effective (Bahrick 1979).

Is There An Optimal Spacing Interval? As noted above, spaced studying generally shows better learning than does massed. Is there an optimal spacing? How long must an interval be to be considered spaced, and therefore beneficial? The answer depends on how much time is between studying and the test. In general, the longer the interval before the test occurs, the wider the spacing during study should be. As we move from retention intervals of minutes or hours, characteristic of many laboratory experiments, to retention intervals of days, weeks, and months, characteristic of academic learning, the spacing between separate studyings must increase dramatically. Spaced practice intervals of minutes are perfectly effective if the test will occur at the end of the hour-long experimental session. When the test is a week away, spacing the initial presentations a day or so apart is better.

The most effective spacing can best be described as a ratio of the length of the spacing interval to the length of the retention interval (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). For instance, spacing two periods of study one day apart, and testing seven days later, produces a ratio of 1/7, or about 14%. That same spacing of one day between study periods but testing 30 days later produces a ratio of 1/30, or about 3% (in round numbers). Optimal ratios are said to fall in the range of 10–20 percent. So, the longer the retention interval, the longer the spacing intervals should be to produce a ratio within this range. However, further increases in the spacing interval seem to convey no additional benefit, and may actually decrease learning when forgetting occurs between the two studyings. For instance, spacing intervals of 1 day, 2 days, or 4 days were about equivalent when the test occurred 10 days after the final studying (Pashler, Rohrer, Cepeda, & Carpenter, 2007).

Generation Effect

In most of the experiments presented so far in this book, the researcher presented the to-be-remembered material. The participant looks or listens and tries to remember. An alternative means of presentation is to have the participant involved in presenting the to-be-recalled items. Slamecka and Graf (1978) described a procedure in which their participants generated the target items in response to certain cues. For example, in the following word pairs, fill in the blanks with a word that is opposite in meaning: HOT: _ _ _ _; STOP: _ _. Participants who generated the words COLD and GO were more likely to recall these words later than did subjects who simply read the word pairs. Numbers that are answers to simple math problems are remembered if participants do the arithmetic themselves rather than simply reading the results (Crutcher & Healy, 1989). The *generation effect* is increased memory performance on study material that is generated by the participant rather than being externally provided. The generation effect has been shown in a variety of situations. Enhanced memory occurs in free recall of the generated words, in cued recall in which the first word of each pair is presented as a cue for the second, and by recognition in a multiple-choice format (Burns, 1990, who also notes some complications).

Participant generation of the target material seems to induce elaborative processing that the read-only condition does not. The words must be meaningfully comprehended, and the participant must attend to the relationship between the cues and generated items. Having the participant generate the target word also mimics what will be required later during testing: Produce the to-be-remembered item in response to some cue. This is exactly what the transfer-appropriate processing account discussed in the last chapter would predict: Recall is improved when the encoding and retrieval (or testing) requirements are more nearly alike.

Limitations of Elaborative Processing

I have described several variables that can lead to improved recall and that support the general claim that elaborative processing leads to better encoding. Are there any limits to the benefits of elaborative processing? Are there tasks for which elaboration does not help, or maybe even interferes with learning?

Implicit memory may be one such exception (Schacter, Chiu, & Ochsner, 1993; see Chapter 7). Implicit memory refers to tests of retention that occur without reference to the previous learning task, and therefore in the absence of explicit awareness. For example, after subjects have read a list of words, instead of asking for explicit recall of the words, we might test recall implicitly with a word-fragment completion test. Some letters and blanks are given, for example, C_A_K. The missing letters can be filled in several ways (e.g., CHALK or CRACK). A priming effect occurs when the previously seen words are offered as solutions in the word-completion task: The studied words are "primed" in memory, and so are readily "seen" in the fragments. Implicit tests of memory are often coupled with incidental learning at the input stage. The participants are not told to learn the material, and at the output, we do not remind the participants of their previous encounter with the material.

As it turns out, many of the variables that enhance explicit memory have little or no effect on implicit memory. One variable, for example, is the depth of processing. During the study phase, the subjects can be requested to make shallow or deep judgments about the list items. Deep processing leads to better explicit memory, but does not affect the likelihood of completing word fragments with the studied items (Bowers & Schacter, 1990; Graf et al., 1984).

Another potential limitation of elaboration is specific to verbal elaboration. Verbal description of nonverbal information such as pictures and faces can lead to less accurate retention. In essence, we remember the words we used to encode an item rather than the event itself. A prime example of this *verbal overshadowing* is memory for faces (Schooler, Ryan, & Reder, 1996). In trying to describe a face, we tend to focus on those features that are verbalizable (such as eye color or the shape of the lips) and not on features that are difficult to articulate (such as the configural arrangement of facial features) but that may be more important for face recognition. Verbal overshadowing occurs in other tasks, such as remembering the taste of specific wines. Novice and expert wine tasters were asked to taste and verbally describe several wines. Later, they were given a recognition test to distinguish the tasted from new wines. The untrained tasters did worse when they had verbally described the earlier wines. Not having a sophisticated vocabulary for describing wine, the participants tended to remember what they said rather than what they tasted. Expert tasters were not impaired by verbalization; presumably, their vocabulary matched their subtle taste discriminations (Melcher & Schooler, 1996).

Learner Variables

The learner brings a number of characteristics to the learning situation. Factors such as age, gender, personality, and learning style are discussed in the final chapter of this text. Here a number of other learner variables that can influence encoding are considered, including the intention to learn, the presence of incentives, interest in the target material, and the level of arousal.

Incidental versus Intentional Learning

A paradox involving everyday memory is that often we just seem to spontaneously remember things without any deliberate intention to remember and without any mnemonic preparation. You can probably remember what you had for breakfast this morning and something you read earlier in the newspaper. This is *incidental learning.* At other times, in order to remember, we need to deliberately study, rehearse, and so on. This is *intentional learning.* How necessary is intention to remember? To anticipate the discussion that follows, how much we learn and remember is more a function of how we think about the material and less about our intention to remember it.

The general experimental design used to demonstrate incidental learning is to present a series of words with instructions to the subjects to process the words in different ways. They might be asked to state whether the word has an *e* in it, to rate the pleasantness of the words, or to assign the word to a semantic category (Craik & Tulving, 1975; Hyde & Jenkins, 1969). These orienting tasks require different levels of processing. After this, the participants are given a surprise test of memory. More of the words are recalled that had received semantic analysis, and the participants who performed the deeper processing recalled as many words as participants who were told in advance about the memory test. Incidental recall can be as good as intentional.

Incidental learning occurs as a function of a variety of cognitive operations. Even experts sometimes remember better incidentally. Medical students and medical school faculty were given patient protocols containing about 20 pieces of information, mostly laboratory test results. The participants were asked to diagnose the patient or to try to memorize the case data. The medical specialists who made a diagnosis recalled more specific facts than did the students who diagnosed or memorized. Paradoxically, the physicians actually recalled less when they tried to memorize (Norman, Brooks, & Allen, 1989).

This is not to say that the intention to learn is without effect. An intention to learn can bring to bear additional cognitive resources, such as rehearsal, imaging, or elaboration, that might not otherwise be engaged. Research on incidental learning makes the point that a variety of ways of processing information will facilitate remembering.

Incentives

The psychology literature on reinforcement clearly shows that reward can increase responding (e.g., Bolles, 1975; Spence, 1956). Can reinforcers also be used to increase performance in memory tasks? The experimental data indicate that once a subject has committed to learn, reward has little additional effect. When separate groups of college students were offered different sums of money for each word remembered, 10 cents versus 1 cent, there was no difference in the number of words recalled. Out of 40 words, the dime group recalled 55 percent whereas the penny group recalled 51 percent (Nelson, 1976). In another study, offering $10 to participants if they were among the best in the experiment did not produce any better memory than not offering an incentive (Nilsson, 1987). Given that the participants were motivated and were trying to remember to begin with, as is typical of college student participants, the amounts offered had no additional effect.

There is an important limitation to the preceding generalization, based on whether each participant received a single reward amount or was offered different amounts for different items. If students are informed that some of the to-be-remembered words are worth more money and some less, they now remember more of the dime words and fewer of the penny words (66 percent versus 49 percent; Nelson, 1976). In these cases, a rational strategy is employed: Given a fixed amount of time for rehearsal, devote it to the high-value words and not to the low-value words. This is not unlike what students do in juggling their work load among courses: Devote more time to the important courses (maybe psychology of learning) and less to other classes.

What about incentives offered after learning, at the time of testing? Again, differences in reward amount have little effect here. In one study, a list of 75 words was studied. One week later, the students came back to the lab and attempted to recall as many words as possible. After this first test, some participants were offered $1 for each additional word they could recall. The average number recalled was 5, the same as by the participants not offered the incentive but simply asked to try and remember some more (Nelson, 1976; see also Nilsson, 1987).

A few caveats are in order here. The promise of an incentive for remembering does not affect memory itself but rather behaviors that will lead to better retention, such as rehearsal or cognitive elaboration. Also, the previously described experiments used college students, who were probably intrinsically motivated to try their best regardless of incentive. There may have been little room for further improvement in the incentive conditions. Incentives may be more important in the real world, where rewards might motivate individuals who are not even attempting to learn or recall.

Interest

Having a personal *interest* in the to-be-learned material will usually increase retention. Interest affects attention and contact with the material, and it may lead to deeper cognitive processing of the material.

People with interests in certain topics seem to readily acquire new information within that domain. Some of this is because prior knowledge facilitates acquiring new knowledge. Experts more easily acquire new information in their field of expertise than do novices. However, interest also contributes in other ways. In one study, British soccer (they call it football) fans were asked to memorize lists of football scores. The fans were informed that some scores were real and some were simulated. The degree of expertise of the fans predicted memory for actual scores but not for simulated scores. Emotional involvement with favored and rival teams led to better recall of the real scores. Simulated scores did not evoke this interest because they had no implications for real standings among the teams. This is a nice example of when even expertise in a field does not guarantee better memory (Morris, Tweedy, & Gruneberg, 1985).

Different levels of interest may explain why women might recall personal relationships with more clarity and vividness than do men. Ross and Holmberg (1990) asked couples to evaluate autobiographical memories of relationship events, such as their first date or a recent argument. The ratings given by the men and women in the couples differed. Women not only gave higher ratings for clarity or vividness of the memory and believed they recalled more details, but, in particular, they also rated these events as being of greater personal importance. (Of course, these subject evaluations do not say anything about how accurate these recollections were.) The researchers also considered the possibility that for women, relationship is a domain of expertise. Experts usually have excellent recall within their area of expertise, and so women would be expected to do well with relationship memory.

Arousal

We could expect arousal to facilitate learning, and generally it does. One can almost always find this commonsense result, but equally as often, the findings must be qualified by interacting variables. One limitation is that the term *arousal* is ambiguous and has different meanings as a variable in psychological research. Arousal can refer to a psychological state of attention or alertness; to physiological arousal as assessed by measures of heart rate, skin conductance response (SCR), or EEG; or to a trait, such as anxiousness or impulsivity, indicated by self-report ratings.

Another important qualification is that the optimal level of arousal for any given task varies. Performance is usually better at some intermediate level of arousal and is less efficient at both lower and higher levels. A corollary to this is that different tasks have different optimal levels. These two statements together define the *Yerkes-Dodson law* (1908): Performance follows an inverted U-shaped curve, with peak performance occurring at intermediate levels of arousal and decreased performance at higher or lower levels (see Mandler [1992] for a contemporary discussion). As a hypothetical example, remembering facts from a classroom lecture might be poor if you are either too fatigued or too hyper. It is also likely that taking an exam or demonstrating video game skills requires different optimal arousal levels than does classroom learning.

A real-world example of the Yerkes-Dodson law is the recall by 3- and 4-year olds of a hurricane they had experienced (Bahrick, Parker, Fivush, & Levitt, 1998). Arousal was defined by the amount of damage to the house produced by the storm: High arousal was assumed in cases where the house was penetrated, moderate arousal if there was extensive outside damage, and low arousal if the damage was minimal. The number of facts recalled as a function of arousal level are shown in Figure 9.5. More was recalled by the moderately stressed children than by those presumed to have experienced lower or higher levels of arousal.

There are several kinds of evidence that suggest arousal is important for learning. Arousal has been manipulated directly through the administration of stimulant drugs and indirectly through correlations with circadian rhythms. We can also consider the effects of extremely low levels of arousal, such as sleep (see Box 9.2), and extremely high levels of arousal, such as that produced by strong emotions (discussed separately in a following section).

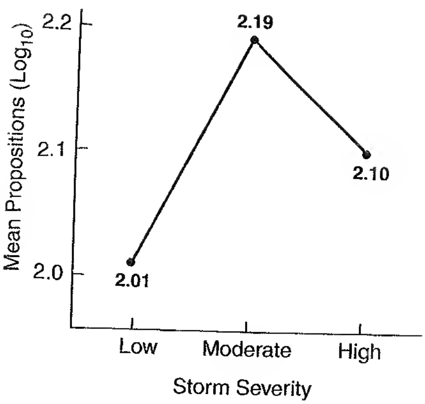

FIGURE 9.5 Mean number of facts recalled (the means are log-transformed) by 3- and 4-year olds as a function of hurricane damage.

Source: From "The Effects of Stress on Young Children's Memory for a Natural Disaster," by L. E. Bahrick, J. F. Parker, R. Fivush, & M. Levitt, 1998, *Journal of Experimental Psychology: Applied, 4*, p. 318. Copyright © 1998 by the American Psychological Association.

Stimulant Drugs. Stimulant drugs that increase central nervous system arousal should also increase learning. The stimulant strychnine, a poison when taken in higher doses, was an ingredient in tonics once prescribed for memory loss and forgetfulness (Essman, 1983, p. 131). The behaviorist psychologist John Watson claimed the only reason he passed his final exam in Greek was that he drank a quart of cola syrup, which contains caffeine, while cramming overnight (Watson, 1936). However, it is unclear whether these stimulants actually increase learning (e.g., by facilitating encoding) or simply affect performance (e.g., reducing fatigue) (Essman, 1983).

Unfortunately, there are no simple effects of most stimulants on learning. Caffeine has produced complex interactions with other variables such as personality, gender, age, the time of day, and the type of memory task (Hogervorst et al., 1998; Revelle et al., 1980). Immediate free recall of word lists by women was, in one case, impaired following a dose of caffeine (Erikson et al., 1985), and, in another study, enhanced (Arnold et al., 1987). Caffeine had little consistent effect on men in either study. Why were women affected? In one case, a cognitive explanation was offered suggesting that caffeine-induced arousal interfered with rehearsal. In the other case, a biological explanation said that caffeine combined with estrogen levels to enhance arousal. Arousal is the common theme, but at two different levels of explanation.

I do not want to overemphasize the arousal-producing aspects of drugs to the neglect of the other effects they may have on memory formation. Any drug that has stimulating or depressing effects on the central nervous system can affect neurotransmitter activity, for example, apart from any general arousal effects. For example, the drug lorazepam, which is used to reduce anxiety, both reduces central nervous system arousal and inhibits the action of some neurotransmitters. The effects of this drug were compared to those of a control drug that only decreased arousal but was not known to affect other brain chemicals related to learning. (The researchers used an antihistamine as the control drug, and you know what antihistamines can do to your level of alertness.) The lorazepam subjects remembered much less than did the antihistamine subjects in tests of word recall and recognition (Curran, Pooviboonsuk, Dalton, & Lader, 1998). That is, the antianxiety drug impaired memory whereas the antihistamine did not.

BOX 9.2

Sleep Learning

Does learning occur while we are asleep? An entire industry has developed around the promotion of sleep-learning tapes. Simply play the tape through a pillow speaker during the night and wake up the next morning refreshed and fluent in Spanish! But if the sleep state is one of low arousal, can anything really be learned then?

The results of many early studies were inconsistent, sometimes showing learning and sometimes not (see Aarons, 1976). The discrepancy seemed to be due to whether the participants were actually asleep when the tapes were played. No learning occurred if the material was presented when the participants were truly asleep, as verified by EEG and REM recordings (not REM the band, but rapid eye movements). For example, Emmons and Simon (1956) presented a 10-word list *46 times* during the night. The list was played only when EEGs indicated the participant was in deep sleep. The tape otherwise was stopped. When tested with a five-option multiple-choice test the next day, the participants recognized a hardly encouraging 25 percent of the target words, as compared to a chance level of 20 percent. On the other hand, researchers who adopted a pragmatic philosophy about instruction would simply play the tapes from lights-out until wake-up the next morning. Some learning did occur under these conditions, but most probably occurred when the participants were drifting off to sleep or during awakenings during the night.

Some forms of learning do occur during sleep. Simple classical conditioning and habituation (a decrease in orienting reactions to an irrelevant stimulus) have been demonstrated to occur in sleeping animals and humans (see Badia, 1990).

Why are dreams so poorly recalled? If you are awakened during REM sleep, often a dream is recalled. If you are awakened minutes after leaving REM the dream has already slipped away. One theory is that dreams are briefly retained in short-term memory, but in the absence of sufficient arousal, the dream is not encoded into long-term memory (Koulack & Goodenough, 1976). Of course, dreams may be forgotten for other reasons discussed in this chapter: the images and events in our dreams are not always meaningful; they are not logically organized; and they do not conform to our waking schemas. There seem to be gender differences in dream recall: Women report higher frequencies in dream diaries (Martinetti, 1989). We can only speculate as to the reasons for this. Possibly, women's dreams are more organized and meaningful.

Sleep *after* learning has a different effect than sleep during learning. A classic study by Jenkins and Dallenbach (1924) showed that 8 hours spent sleeping after learning was more beneficial than 8 hours spent awake. One interpretation of the results is that sleep protected the newly learned material from interference due to waking activity. Recent research has suggested a different explanation: Sleep is an important time for consolidation of the memory traces into permanent memory. During sleep, those neural elements that were active during learning become reactivated during sleep. This has been referred to by analogy to "offline processing" (Stickgold, Hobson, & Fosse, 2001). In back-to-back articles published in the journal *Science*, researchers showed that postlearning REM sleep enhanced learning of spatial mazes by rats (Wilson & McNaughton, 1994) and an eye movement motor skill in humans (Karni et al., 1994). Disruption of the REM stages of sleep impaired later retention. So, in a sense, learning does occur during sleep—the learning that began before sleep commenced.

Remembering under Anesthesia?

Learning while anesthetized poses similar research problems to sleep learning, primarily knowing whether the subject is truly unconscious. There may be some consciousness even though pain and movement are blocked (Andrade, 1995). In experimental tests of the effects of low doses of inhaled

(*continued*)

Box 9.2 Continued

anesthetic drugs, memory on verbal tasks such as the digit span and free recall was poorer (Adam, 1979). Interestingly, implicit memory was found after surgical anesthesia (Kihlstrom et al., 1990). Pairs of moderately associated words (such as TABLE and KITCHEN) were repetitively read to patients during surgery, with the intention of strengthening the words' associations. Half of the participants heard one list of word pairs, and the other half heard a second list. Thus, the unheard lists provided baseline rates of free associations later. On two occasions after surgery, the participants were given free-association instructions. The first word in each pair was presented and the participants were asked to respond with the first word that came to mind. More of the moderately associated words presented under anesthesia were recalled than if these associations had not been heard. Thus, implicit memory may be one form of learning that can occur under low levels of arousal.

Circadian Rhythms and Learning. Arousal varies during the course of the waking day. Do circadian variations influence learning ability? In one study of digit span, a measure of short-term memory, performance peaked at about 10:30 A.M. and declined thereafter into the early evening hours (Blake, 1967; see right panel of Figure 9.6). Immediate recall of specific facts from a 1,500-word science article peaked even earlier in the morning: Correct recall was maximal at 8 A.M. and steadily declined thereafter, with a slight bump back up after lunch (Folkard & Monk, 1980; left, Figure 9.6). (These studies both used British students. I would be surprised to see U.S. students peaking at that hour in the morning.)

One difficulty in linking levels of arousal to circadian rhythms is the assumption that everyone has the same cycle. If people differ in their levels of alertness at different times of day (i.e., so-called morning "larks" and evening "owls"; Guthrie, Ash, & Bendapudi, 1995), there may be parallel differences in recall at different times of day. Indeed, one study found that morning people were more accurate in paragraph recall when tested at 9 A.M. than at 8 P.M., whereas evening people did better at the later testing time (Petros, Beckwith, & Anderson, 1990).

Some Conclusions about Arousal. An implicit assumption of arousal theories is that an aroused brain simply works better at consolidating information into a stable memory. It is as if once the brain is cranked up, anything thrown in will be remembered better. Apart from any hypothesized neural effects, we need to consider the broader influence of arousal on cognition. Arousal affects what we attend to and what is ignored, what and how we encode, and how efficiently we retrieve. The source of arousal will also have different effects. Arousal elicited by a startling unknown sound will affect learning differently than arousal produced by loud but familiar background noise.

Emotions and Encoding

Are highly emotional events remembered better than neutral events? This question seems too easy and the answer seems too obvious. However, getting objective data to support our subjective impressions is not so easy. The two basic problems are determining whether what we recall is accurate and exactly how emotions influence remembering.

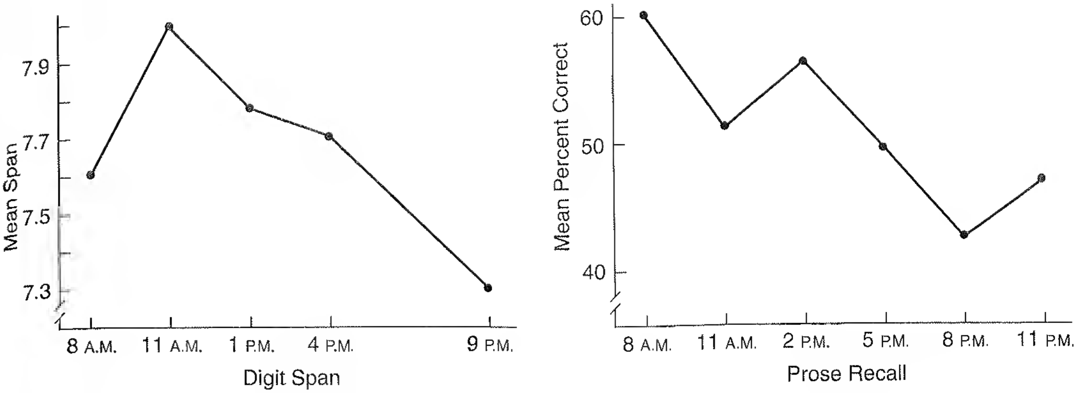

FIGURE 9.6 Digit-span recall (*left panel*) and prose-paragraph recall (*right panel*) as a function of time of day of testing.

Source: (*Left panel*) Blake, 1967. (*Right panel*) From S. Folkard and T. H. Monk, "Circadian Rhythms in Human Memory," *British Journal of Psychology, 71*, pp. 295–307, 1980. Reproduced with permission from the *Journal of Psychology*, The British Psychological Society.

How Do Emotions Affect Memory? First, emotional arousal will focus attention on certain aspects of a situation. Given our limited capacity to divide attention, this means that peripheral details may go unnoticed. In an experimental simulation of memory for an emotional event, a vignette (or story) was presented via a series of seven slides, and, simultaneously, the participants' eye movements were recorded. When one slide depicted an emotional outcome to the story (a child hit by a car), there were more fixations on the central details of the picture. These details were also recalled better than in the neutral condition, but peripheral details were not recalled as well in the emotional condition. Does this mean that overt attention alone explains memory for detail? No. In another version, the critical slide was presented for 180 milliseconds: long enough for a single eye fixation, but not long enough for eye movements to differ between emotional and neutral slides. Nevertheless, central detail memory was better for the emotional slide (Christianson et al., 1991).

A second effect of emotion is to produce bodily arousal that could contribute to long-term memory formation. Epinephrine is released from the adrenal medulla during and after an emotional stressor, which activates receptors in the body, which in turn lead to stimulation of the amygdala in the brain. The amygdala has been implicated in the formation of long-term memory for emotional events in animal conditioning studies (McGaugh, 1991; Thompson & Gluck, 1991).

Third, emotional events are distinctive. Often, they are not everyday experiences. Emotional events are talked about and thought about, and so they are well rehearsed and elaborated in memory (Heuer & Reisberg, 1992). In the extreme example of post-traumatic stress disorder, the memories replay and intrude into thoughts and dreams.

Thus, emotions incorporate several themes from this chapter: attention, arousal, distinctiveness, and elaboration. (Emotions may also affect retrieval, either to facilitate or inhibit recall. These latter possibilities are discussed in the next chapter.)

Flashbulb Memories. One striking memory phenomenon that most of us have experienced is that of having a vivid memory for a surprising, emotional, and consequential event. For many of us, the precipitant is particular to our own lives, for example, unexpected tragic news or unexpected good news. Others are for events that are shared by a community or a nation, such as the news of the attacks on September 11, 2001. Brown and Kulick (1977) used the term "flashbulb memories" to capture the essence of such memories. It is as if a picture of that moment when we heard the news is encoded into memory. This image is assumed to be complete, detailed, and accurate. Brown and Kulick proposed the existence of a special memory mechanism, triggered by surprising and emotional events, that immediately creates a record of the contents of consciousness at that moment. These memories are immune to forgetting. Presumably this mechanism evolved as a means of survival in primitive humans (and animals) to handle memory for consequential events that might recur.

The method introduced by Brown and Kulick to study flashbulb memories was to ask people if they remembered when they first learned of a significant news event, such as the assassination of President John F. Kennedy or Martin Luther King, Jr. Even long afterwards people reported photolike memories. These included details of where they were when they heard the news, what they were doing at the time, from whom or how they heard the news, their immediate affective reactions, and what they did next. Interestingly, among both black and white respondents, John Kennedy's death was an event that most frequently provoked a flashbulb memory. Martin Luther King's death was more often remembered in this manner by black Americans than by whites.

Neisser (1982) criticized the Brown and Kulick procedure on several grounds. What people claim they remember is not necessarily true, no matter how vivid the memory seems to be. Jean Piaget distinctly remembered being kidnapped as a young child and often retold the story, although he later learned this had not happened (cited in Loftus & Ketcham, 1994). Neisser also argues that the memories may be formed, not in a flashbulb instant, but in the hours or days afterwards, when people tell and retell their story. Indeed, people's recollections do have a news-reporting quality to them: when, where, why, who, and what.

Researchers next moved to questioning subjects soon after a traumatic experience and then retesting them months later. The accuracy of memory on the delayed second test is verified by comparison to the first memory test, a method which presupposes people remembered accurately during the first test. McClosky, Wible, and Cohen (1988) questioned people about flashbulb memories for the space shuttle *Challenger* explosion 1 week afterwards and again 9 months later. The participants evidenced remarkable consistency (94 percent overall) in their answers to specific questions about where they were, who told them, and so on. Over time, the memories did become more general and contained fewer details. But about 9 percent of the "facts" remembered 9 months later were inconsistent with the 1-week recollections, and about 6 percent of the facts were forgotten. One could be impressed by the robustness of the memories: These are very good memories. Or, like McClosky and colleagues, one could focus on the forgetting: These memories were not perfect, unchanging, or immune to forgetting.

Are flashbulb memories remembered any better than everyday memories? Is there really a special mechanism for a special type of memory? Talarico and Rubin (2003) interviewed college students the day after the September 11 attacks, asking them about where they were, how they heard, who was with them, and so on (the sorts of things we recall about flashbulb memories). The students were asked the same questions about some everyday event that had occurred near 9-11, which often turned out to be a school-related or social event. When the students were interviewed again 32 weeks later, they showed fairly consistent recall of the 9-11 details, forgetting a few and adding some others. Their memories were rated as "vivid," which was as expected for flashbulb memories. Remarkably, the students' recall of the everyday events was no different. They recalled the same number of details that were consistent with their previous statements and the same number of details that were inconsistent. Their flashbulb and everyday memories did not differ. What did differ was that the students were more sure of the accuracy and veracity of their flashbulb memories.

Is there a separate flashbulb mechanism? Maybe instead we should view memory as a continuum, with different factors such as surprise, emotionality, consequentiality, or rehearsal acting to push memories toward one end point or the other.

Eyewitness Memory and Emotional Arousal. Eyewitness recall may offer another source of data on the effect of emotional arousal on memory. Are witnesses to a crime or an accident, who have been exposed to an emotional event in a realistic situation, more or less likely to recall significant details? Once again, there is no simple answer, because recall is determined by a complex set of interacting variables. Emotional arousal may lead to focusing and retention of central details, but poorer retention for peripheral and unattended details. One example of this is labeled *weapons focus*: Victims or witnesses focus attention on a weapon, but possibly do not remember other details of the situation, such as the face of the perpetrator (Loftus, Loftus, & Messo, 1987). In one study of weapons focus, participants who thought they were waiting for an experiment heard an argument in the next room. Someone emerged from the room carrying either a pen or what appeared to be a bloody letter opener. The participants were then tested for face recognition of this person, which was the real purpose of the study. The perpetrator's picture was less often identified in the weapon condition than in the pen condition (cited in Loftus, 1979). An emotional witness and a nonemotional person might remember equal amounts of information, but different details of the situation.

A traumatic experience may also produce retrograde or anterograde amnesic effects (or both), so that certain details will be forgotten due to their temporal placement relative to a startling event. Loftus and Burns (1982) showed a 2-minute video depicting a bank robbery, a film used by banks to instruct their employees on how to handle this kind of situation. Toward the end of one version of the film, a bank teller is shot, but this does not happen in the control version. Participants who viewed the first version of the film did not recall a critical fact shown just before the violent act: the number on a bystander's football jersey. Only 4 percent of those seeing the violent film remembered it, whereas 28 percent of the control participants did. Christianson and Nilsson (1984) found forgetting on the other side of the traumatic event. Their participants did not recall a critical detail that followed the arousing stimulus.

Conclusions about Emotions and Memory. Emotional arousal can facilitate encoding into memory. But knowing this fact will not tell us what details will be encoded. Remembering a suspect's face would be helpful to the police, but the victim's attention may have been focused on a weapon. Significant details that preceded or followed a startling moment may be forgotten. Rehearsal may elaborate some of the memories, but at the same time can introduce distortions. To this list, we can add other forgetting factors. Details may be remembered, but their temporal order is not, leading to misrecall of the sequence of events. Forgetting the source of what is remembered, some facts that were heard about or thought of, can lead to misrecall of these details as having been actually perceived (Johnson & Raye, 1981). We are therefore limited in our ability to make broad statements about the effects of emotion on the accuracy of memory.

Schemas

Schemas are outlines of general knowledge that are stored in semantic memory. Schemas, also called scripts, scenes, or frames, are ways of organizing knowledge. Schemas are often hypothesized to have a hierarchical structure, with packets of information stored at each level. One often-cited example is the "restaurant script," as listed in Table 9.1. At the top of the hierarchy is the label "going to a restaurant." The next level down has subordinate categories, such as entering, ordering, eating, and exiting. Within these categories is general knowledge about each step: Ordering involves reading the menu and telling the server what you want; exiting involves paying the bill and leaving a tip.

Alba and Hasher (1983) noted that there are several ways a schema can influence what is learned in a given situation.

1. *Selection.* Schemas guide selection of what is to be encoded, usually details that are relevant to the schema.
2. *Storage.* A schema can organize memory for events, providing an outline of where each new piece fits.
3. *Abstraction.* Common features across a number of similar experiences are abstracted and stored in the schema; specific details from any one event need not be retained.

TABLE 9.1 Restaurant Schema

1. Entering
    - Customer enters
    - Looks for table
    - Sits down
2. Ordering
    - Looks at menu
    - Signals server
    - Orders food
3. Eating
    - Server brings food from kitchen
    - Food brought to table
    - Customer eats
4. Leaving
    - Server brings check
    - Customer leaves tip
    - Customer pays cashier

4. *Retrieval.* A schema provides retrieval cues to guide and direct memory search.
5. *Normalization.* The schema may lead to memory distortion, in that we remember what usually happens, as recorded in the schema, rather than what actually happened.

There are some nice examples of schema influence in studies of remembering the objects in a room. Rooms used for different purposes, say, an office, a classroom, or a dorm room, typically contain different items. Pezdek and colleagues (1989) had their participants view one of two rooms: a graduate student office and a preschool classroom. Each contained schema-consistent objects (books, a beer bottle, and a desk; or toys, games, and blocks); or schema-inconsistent objects (simply exchanging some things between the office and preschool room). The results of this study make several important points about what is and is not remembered. Items highly relevant to the schema are remembered, for example, books and a chair in an office. Unusual or unexpected items were recalled even better, for example, a toy truck in a graduate student's office. However, objects that are neither schema-relevant nor unexpected seem to get lost. There was a clock radio in the office. We don't expect it to be there, yet its presence is not surprising either. It is forgotten. (I was once surprised to see a playpen in an associate dean's office. He had been babysitting his grandchild that day. This is a schema-inconsistent item and was thus memorable.)

Schemas unfortunately can lead to misencoding. When students in a speech-and-hearing course were shown a list of symptoms that led them to make a diagnosis of a specific hearing disorder, they later misrecalled some symptoms that had not been presented but that were consistent with the diagnosis. They remembered what is typical for this disorder. On the other hand, making the diagnosis improved recall in one way: On a recognition test, the participants were able to correctly reject symptoms unrelated to the diagnosis that had not been seen before. There was a trade-off between the memory-improving and memory-distorting effects of the schema (Arkes & Harkness, 1980).

Another example of distortion arises when sex-role stereotypes affect what is remembered. If the target material is schematized as being male-oriented or female-oriented, then men and women may remember the same material differently. Separate groups of college students were read a vaguely worded, nonspecific prose passage of several hundred words that was titled "Making a Shirt" or "Building a Workbench." Sentences included: "First you rearrange the pieces into different groups. . . . Work slowly on one part at a time. . . . Make sure they are the right pieces. . . . At first they may not seem to fit." On testing, women recalled more ideas from the shirt example than did the men, but men recalled more of the workbench story. Yet everybody had heard the same sentences. The titles apparently activated different schemas within which to encode the vaguely worded instructions (Hermann, Crawford, & Holdsworth, 1992).

As memory for repeated events becomes schematized, specific details may become lost. Linton (1982) kept an index card diary of personal events in her life for 6 years. She periodically tested herself by sampling items and trying to determine whether she really remembered the events. She reported forgetting specific details when an event was repeated. For example, early in her study, Linton could recall details of the first meeting of a committee to which she was appointed. As more meetings accumulated, details of each became blurred, and, instead, a more generic memory (or schema) developed. Now, specific events that differentiated one meeting from another (where they had lunch one day or who missed a given meeting) were lost. A similar finding was seen in kindergarten children who attended a series of workshops. They could recall more of what typically happened during the sessions after four visits than after one. They had by then formed a generic memory of the sequence of events. However, they began to lose memory for details, such as misrecalling events from one week to another (Hudson, 1990). Once a schema is formed, memory for specific details declines.

Strict adherence to a schema would allow recall of only those events that conform to the schema. However, exceptions to the rule are remembered, especially if they are unusual or surprising. Isolation or von Restorff effects can still occur. And schemas can undergo change, as new examples are assimilated into the schema. The restaurant schema you first developed as a child, likely based on fast-food outlets and Happy Meals, is modified as you experience different types of eating establishments.

Metamemory

In this chapter we have presented many factors that affect learning. In addition, learning will be importantly influenced by our knowledge of when and how these factors work and our beliefs that they will indeed work. *Metamemory* refers to our knowledge about memory. It includes our estimates about the difficulty of learning certain materials, which strategies we think will be most useful, monitoring our progress during learning, awareness of what we know and do not know, and beliefs about how our own memories differ from memory in general. (Metamemory also includes knowledge about retrieval, which will be discussed more in the next chapter.)

Metamemory is usually assessed by a self-report questionnaire, the scores on which can then be correlated with actual memory performance. For example, students can be asked to make "ease-of-learning" judgments, possibly using a 10-point scale, prior to actually attempting to learn material. U.S. students should predict that their learning the capitals of former Soviet republics will be more difficult than learning the county seats of a U.S. state. When the students subsequently attempt to learn a set of facts, they actually spend more time on the items they had predicted would be more difficult (Nelson & Leonesio, 1988). *Judgments of learning* (JOL) are ratings taken after studying, but before testing, when subjects rate how well they think they have learned the material. These estimates often predict how much of the material is recalled on an actual test.

What factors guide a student's decision that they have studied sufficiently or not? Judgments of learning are primarily affected by characteristics intrinsic to the material. In the case of remembering lists of words, the imagery value of words or the degree of associative relatedness affect JOL ratings. Extrinsic conditions of learning, such as increasing the number of repetitions or spacing the repetitions, do not increase JOL ratings. Under these study conditions, later recall was much better than the students predicted. Certainly, students are aware that spacing and repetition facilitate learning, yet having studied under these conditions does not increase the belief that more learning has occurred (Koriat, 1997).

Metamemory perceptions show a developmental progression. The use and elaborateness of rehearsal increases as children age, as does their metamemory belief that rehearsal is beneficial. Five-year-olds realize that teenagers have better memories and that the five-year-olds have better memories than do their younger siblings. Older children can predict better when they are ready to be tested (judgment of learning) than younger children (Kail, 1990). On the other hand, even very young children have accurate perceptions of when memory might fail. When asked how they could remember to bring something to school tomorrow, they offered reasonable strategies such as placing the object near the door or in their school bags or asking Mom to remind them (Kreutzer, Leonard, & Flavell, 1982).

Individuals thus possess some general knowledge of learning and remembering. In addition, they have knowledge of how good their own memories are. This is referred to as *memory self-efficacy*: Judgments about how effectively we think our memory will function in a particular situation. Self-efficacy can be assessed through self-report inventories, such as that presented in Box 9.3. Individual differences in self-efficacy beliefs are dramatically shown in comparisons of younger and older adults (Ryan, 1992). Participants aged 25 to 85 rated self-perceived memory for such things as conversations or names, and the incidence of absentmindedness. Both older and younger participants believe that, in general, memory declines with aging. However, most people, young or old, did not think their memories are as bad as those of others their age. Personal self-efficacy, in this case, was rated better than the perceived effectiveness of memory in general for an individual's own age group.

The direction of cause and effeet between self-efficacy beliefs and actual performance is debatable. Certainly, low expectations will limit effort devoted to trying to remember. I often hear students complain that they just cannot learn some type of material (foreign languages or statistics as examples). These beliefs can be as detrimental as any lack of ability. On the other hand, our self-perceptions may be accurate representations based on our actual experiences. If I constantly forget names, I should correctly believe that I have a name–memory problem.

Conclusion. To understand how new learning occurs, we need to consider several factors: the material to be learned, the context in which learning occurs, the cognitive resources available in different memory structures, the task demands, the existing knowledge base of the subject, the strategies selected, and our beliefs about how learning occurs. The point of this lengthy list is to remind you, once again, of the complexity of obtaining a scientific understanding of the learning process.

Applications

The Future of Memory Encoding

The current chapter descries a number of cognitive and psychological methods to increase encoding of information into memory. The discussion of arousal and memory implicitly suggested that various stimulant drugs might increase learning ability. Chapter 12 considers genetic enhancement of learning and memory. Future advances in knowledge of encoding may well be more biological than psychological. Students now use drugs normally prescribed for attention deficit disorder to increase alertness or increase study time. One recent report suggested that university faculty members who worry about productivity, tenure, and demanding intellectual workloads are similarly using cognitive enhancers (Sahakian & Morein-Zamir,

BOX 9.3

Example Metamemory and Self-Efficacy Items from *Motivated Strategies for Learning Questionnaire*

This is a self-report inventory illustrating aspects of metamemory. Retention is affected by the strategies we use, how well we regulate our learning, our beliefs in our own abilities, the importance of the subject matter, and test anxiety. Students were instructed to respond to these items using a 7-point scale (I = not at all true of me, to 7 = very true of me).

Cognitive Strategy Use

- When I study, I put important ideas into my own words.
- When I study for a test, I practice saying the important facts over and over to myself.
- When reading, I try to connect the things I am reading about with what I already know.

Self-Regulation

- I ask myself questions to make sure I know the material I have been studying.
- I work on practice exercises and answer end-of-chapter questions even when I don't have to.

Self-Efficacy

- I'm certain I can understand the ideas taught in this class.
- My study skills are excellent compared with other students in this class.
- Compared with other students in this class, I think I know a great deal about the subject.

Intrinsic Value

- It is important for me to learn what is being taught in this class.
- I prefer class work that is challenging so I can learn new things.
- I think I will be able to use what I learn in this class in other classes.

Test Anxiety

- I worry a great deal about tests.
- I have an uneasy, upset feeling when I take a test.
- When I take a test, I think about how poorly I am doing.

Each of these subscales showed correlations with academic performance: higher ratings were associated with higher test grades, with the exception of ratings on Test Anxiety, which went with lower academic performance (Pintrich & DeGroot, 1990).

Source: Pintrich & DeGroot, 1990.

2007). A developing field of neuroethics considers the moral and ethical issues involved with the use and potential misuse of memory enhancing drugs. These questions are considered in more detail in Box 9.4.

Academic Learning and Encoding

Elaboration. Consider some student-learning techniques in light of elaborative processing. Underlining in textbooks, taking notes during lectures, and writing summaries are often used by students, but actually may contribute little to learning (Snowman, 1986). Although each could be done in a manner that promotes elaborative processing, students may instead become accomplished at passive underlining and transcribing. For example,

BOX 9.4

Neuroethics and Artificial Memory Enhancement

Among the major news stories in sports in recent years have been reports of athletes who use performance-enhancing drugs. There have been such accusations in baseball, cycling, track, and other sports. There is general acknowledgement among amateur athletic organizations and Olympic sports sponsors that such drugs should be banned. New developments in brain science will likely produce means of artificially enhancing memory. The ethical questions raised by the possibility of drug enhancement of the mind will be many of the same that we now face in athletics.

It is already the case that stimulant drugs used to treat attention-deficit and hyperactivity disorders (ADHD) are being used on college campuses for the purpose of enhancing academic performance. Adderall is prescribed for the treatment of ADHD, yet non-ADHD students buy the drug from students who have legitimate prescriptions, or students falsely claim to have AHDH in order to obtain a prescription. A survey of college students found that about 4% reported using Adderall or Ritalin in the previous year (McCabe, Knight, & Teter, 2005). The numbers were higher in schools that had more competitive admission standards. In parallel to the advantage gained in athletics by those who use steroids, students in high school could learn more and faster, increase their grades, and maybe their college admission test scores, giving the drug-enhanced advantage over those who learned naturally.

The hundreds of thousands of school-age children who in the 1990s were put on Ritalin and other drugs are now in college. A new generation sees such stimulant drugs in school as normal (Jacobs, 2005).

The newly emerging field of neuroethics deals with the moral, social, and scientific decisions that arise from developments in the brain sciences. Artificial remediation of memory is obviously desirable for unnaturally early loss of memory ability, as in Alzheimer's, or due to brain injury earlier in life. Who could argue against restoring a relatively normal memory to those who have been cruelly deprived?

But once the technology becomes available, will individuals without impairment seek an advantage provided by a drug? The list of questions such advances provoke is long: Should people with normal memory be allowed the enhancing drugs? What about using drugs to counteract the normal aging of memory? Will younger people be pressured to take the drugs just to stay competitive, in school or on the job? Can people realistically weigh the side effects and health risks versus the potential benefits? Will only the affluent have access to what will likely be expensive treatments? These are some of the questions that need societal discussion and answers.

Currently some drugs are available for the treatment of Alzheimer's. In the future, drugs will be tailored to specific forms of memory loss. Well known memory researchers, some cited in this textbook, have partnered in businesses to develop chemicals to restore or enhance memory. Companies with names like Memory Pharmaceuticals, Cortex Pharmaceuticals, and NeoTherapeutics are testing drugs with names like Neotrophin and Memantine, as reported in news sources such as Business Week and the NeuroInvestment newsletter (Arnst, 2003; Freundlich, 2001). These drugs will be developed to treat Alzheimer's, but off-label and black-market use will be virtually uncontrollable.

The other side of memory enhancement is forgetting enhancement. Drugs or other techniques might be used to prevent or limit painful, distressing, or traumatic memories. Possibly the adverse aftereffects of a traumatic experience, such as post-traumatic stress disorder, could be prevented by the administration of a memory-blocking drug. This would seem to be a beneficial outcome. Who would oppose this? But maybe not all unpleasant memories should be blocked. After all, we learn from adversity, and blocking the formation of

(*continued*)

Box 9.4 Continued

memories of traumatic experiences might also block the learning that would prevent us from re-experiencing the trauma in the future. There is also the argument that adversity has produced some great benefits. Some individuals may become better people after surviving a trauma, translating their pain into masterpieces of music, art or literature, or new discoveries in science and technology (see *Beyond Therapy: Biotechnology and the Pursuit of Happiness*, The President's Council on Bioethics, 2003). The future sciences of learning and memory may be very different from the present ones.

Hirst and colleagues (1980) had college students extensively practice taking dictation while reading unrelated material simultaneously. The students became proficient at doing both tasks at once, with little cross-interference. This suggests that students might in fact be able to take lecture notes without really attending to the content of the lecture. Some studies of note taking found that students who take notes recall no more than do students who simply listen to the lecture (Kiewra et al., 1991). *Taking notes* might not be as important as *having the notes later,* to review and study.

Other student study techniques promote shallow processing. Students tend to underline too much when reading or include too much verbatim copying while summarizing, which in either case is a passive rather than active strategy. Both underlining and summarizing improve recall when students are limited in the amount of each: for example, only three lines of underlining per page or summaries restricted to three sentences (Kulhavy, Dyer, & Silver, 1975). Note taking improved recall of lecture material when the students were instructed how to organize their notes to promote interrelationships across the material (Kiewra et al., 1991). In these cases, the students have to process the material better to select the most important ideas.

One means of getting students to think about facts they are asked to remember is to prompt them with a question: Why would this be so? These questions force elaboration of the to-be-learned material. In one demonstration of this method of *elaborative interrogation,* Canadian college students studied short paragraphs about universities. In the interrogation condition, they were asked why each fact might be true. A sample fact might be "McGill University stands on land donated by a fur trader." These students recalled more facts and correctly associated them to the universities than did control participants who simply read the paragraphs (Woloshyn et al., 1990). Elaborative interrogation forces subjects to integrate the given facts with existing knowledge.

Meaningfulness. Meaningfulness is enhanced in textbooks that use text adjuncts such as headings, titles, or theme statements to help organize and interpret the to-be-remembered information. As mentioned earlier in this chapter, labels or titles affect recall of prose passages, possibly by activating existing knowledge or schemas that can guide encoding and subsequent retrieval. Other text techniques are advance organizers and analogies. Advance organizers are longer introductory statements that act as a bridge between what the student knows and the new material. Analogies activate prior knowledge to facilitate the understanding of new material that is being presented. Each of these adjuncts can produce meaningful learning that increases retention over longer intervals (Royer, 1986).

Generation Effect. What are the educational implications of the generation effect? Suppose you are required to memorize a series of facts. (For example: Who was the first person to fly solo across the Atlantic? Answer: Charles Lindbergh.) The teacher could present a list of questions and answers for you to read. Or the questions could be followed by some clues for you to generate the correct answer. These clues could be, for instance, an anagram made up of the letters spelling the correct answer, or the answer with certain letters omitted. In either case, you must generate the correct answer. De Winstanley (1995) tested college students in the preceding manner, and found that the generate condition produced better recall of the answers. What was also notable was that this effect was present 2 days later, when the participants were given a surprise test on the answers to the questions.

Self-Efficacy. A motivational factor related to metamemory is the belief that a strategy works and is worth the effort. Teaching students a mnemonic technique that we know from our research should work will not be of much benefit unless the students are convinced it will make a difference in their learning. In the standard intervention design, someone is first taught a mnemonic technique; the method is tested once to show it works; and then you hope the students will continue to use it. Pressley, Levin, and Ghatala (1988) added another step after teaching an imagery mnemonic to assist foreign-language vocabulary acquisition. The students attempted to learn some other vocabulary words using their own methods, whatever those were. The most beneficial training condition was one in which the participants first learned well using the imagery mnemonic, but then learned poorly with their own techniques. Those participants who had clearly seen its power went back to using if for subsequent trials in the study. Other students who were taught the mnemonic simply dropped it when given the opportunity.

Circadian Rhythms. Does time of day affect academic learning and retention? Ebbinghaus conducted an early study for a school system and concluded that the early afternoon was the worst time for academic instruction. N. F. Skinner (1985) found that course grades among Canadian college students at his university were higher in afternoon and evening sections than in morning sections. Unfortunately, enrollment in morning and afternoon sections is a mix of voluntary and involuntary assignments; for example, some courses may be offered only in the morning, or freshmen are forced to take early-morning classes that are the only ones left after everyone else has registered. It is also important to recall that there are individual differences in alertness at different times of day (the morning types, who are bright, chipper, and otherwise annoying at early hours; and the evening types, who are bright, chipper, and normal later in the day). Students who rated themselves high on a "morningness" scale had higher grades in their 8 A.M. classes than later in the day. Low-morningness people had their lowest grades in 8 A.M. classes (Guthrie et al., 1995).

Summary

This chapter focused on variables that primarily affect the encoding of information into memory. However, encoding cannot be isolated from storage and retrieval factors. Most laboratory studies of encoding use episodic learning tasks such as free recall or recognition.

Some Basic Variables in Encoding

Encoding is affected by rehearsal, imagery, and meaningfulness.

A distinction can be made between elaborative rehearsal, a form of deep processing in which the to-be-remembered material is related to other information, and maintenance rehearsal, a form of shallow processing in which information is passively repeated. Elaborative rehearsal promotes better retention through associations to existing knowledge, the formation of distinctive memories, and the effortful processing that it entails.

Elaboration can be enhanced by organization, imagery, or mnemonics. Student study tactics, such as underlining and note taking, are often passive and do not promote much elaboration. The technique of elaborative interrogation, asking "why" questions about the to-be-recalled material, increases retention.

Material that is more *imagable,* or concrete instead of abstract, is better remembered. Pictures and objects are remembered better than are words. This may be because of dual coding of both an image and a word.

Meaningful material is better remembered. Meaningfulness is defined by the high frequency of occurrence in language, ease of pronounceability, number of associations to other items, and concreteness or imagability. Basically, meaningful items are ones you are already knowledgeable about. Material can be encoded better if we can find some meaning to it, as in the case of finding a meaningful pattern in an otherwise random string of numbers or letters.

Presentation Variables

Encoding is also affected by the way material is presented. This section of the chapter included several "effects": the testing effect, the isolation effect, and the generation effect.

The *testing effect* refers to the greater benefit of taking a preliminary or refresher test on recently studied material over additional study, as assessed on later retention of the studied material. The practice test mimics what the students are required to do on the final test, that is, retrieve the information from memory. The practice test may enhance retention of untested information, although retention is better if misrecall is corrected immediately.

A *von Restorff* or *isolation effect* occurs when an unusual item, embedded in an otherwise homogeneous list of items, is particularly well remembered. The isolation effect may be due to enhanced rehearsal or to the distinctive memory representation of the isolated item.

If a to-be-remembered item is presented two or more times, spaced or distributed repetitions produce better recall than do massed repetitions. This *spacing effect* may be due to the total amount of rehearsal that two widely separated items permit, the reduced attention to a closely spaced repeated item, or to different encodings of spaced repetitions. One exception to the spacing effect is that massed repetitions may be better if testing occurs immediately following presentation.

The *generation effect* is increased recall of study material that is generated by the participant rather than being provided by the experimenter. If the participant can be guided to produce the correct information during study rather than simply reading it, retention will be enhanced.

Learner Variables

A number of learner variables that can influence encoding were considered, including the intention to learn, the use of incentives, interest in the target material, arousal, and emotions.

Retention is often more a function of how information is processed rather than of explicit attempts to remember. *Incidental learning,* or remembering without any deliberate intention to do so, is sometimes as effective as intentional remembering.

Offering explicit *incentives* to remember, such as money or points, usually does not improve recall in laboratory experiments. Given that a student-participant is already committed to attempt to remember, incentives do not increase cognitive processing. However, trade-offs may occur if both high- and low-incentive items are presented, as the former are better rehearsed at the expense of the low-incentive items.

People with an *interest* in a particular topic, or knowledge domain, seem to readily acquire new information within that domain. Some of this is because prior knowledge facilitates acquiring new knowledge, but interest also arouses motivation for deeper processing, leading to better encoding.

We expect *arousal* to facilitate learning, and generally it can. However, there are no simple effects of arousal on learning. Each statement about daily rhythms, stimulants, and so on, must be qualified by interactions with multiple other variables. According to the Yerkes-Dodson law, performance is usually better at an intermediate level of arousal and less efficient at both lower and higher arousal levels. The optimal level of arousal varies with task difficulty, such that more difficult cognitive tasks are more efficiently performed at lower levels of arousal than easier tasks.

Circadian rhythms affect arousal and thus possibly indirectly learning and remembering. Some studies have shown better memory in the morning than later in the day. However, there may be individual differences associated with circadian rhythms. Stimulant drugs such as caffeine and glucose can facilitate remembering. Posttraining administration of stimulants enhances remembering, suggesting the effects of arousal are on encoding or consolidation of memory.

Emotional arousal can enhance retention, first by focusing attention on certain aspects of the situation. The weapons focus of crime victims attests to their vivid memory for the central details of a situation and poor recollection of peripheral details. Second, emotion produces bodily arousal (e.g., epinephrine is secreted) that contributes to long-term memory formation. Third, emotional events are distinctive. They are talked about and thought about, and so they are well rehearsed and elaborated in memory.

A flashbulb memory is a particularly vivid memory for a surprising, emotional, and consequential event. It is as if a picture of that moment is encoded into memory.

Some researchers have emphasized the persistence and apparent accuracy of flashbulb memories over time. Others have focused on misrecall and inaccuracy in these memories.

Eyewitness memory is affected by all the complexities involved in encoding, arousal, and emotion in memory. Because of their intense emotional arousal, one could expect witnesses to be good rememberers. Emotional arousal can facilitate encoding, but knowing this fact will not tell us which details are encoded.

Schemas

Encoding is affected by our extensive preexisting knowledge, often summarized in the form of schemas, and by our knowledge of the way memory works.

Schemas, also called scripts, scenes, or frames, are ways of storing and organizing general knowledge in semantic memory. New events are encoded into memory using the existing schema as an organizing guide. Schemas affect attention, selection, abstraction, and normalization. Schemas also influence retrieval, sometimes leading to the misrecall of schema-relevant events. Items that are consistent with a schema (what is expected) and items that are discrepant with a schema (what is surprising) can be well recalled, although for different reasons.

Metamemory

Metamemory refers to our knowledge about learning and remembering. Learning will be importantly influenced by our knowledge of which encoding factors work, our beliefs that they will indeed work, and our monitoring of progress during learning. Self-efficacy, or how effective we believe our memory will be in a given situation, correlates with memory performance, but it is not clear whether poor remembering lowers expectations or whether low expectations reduce performance.